

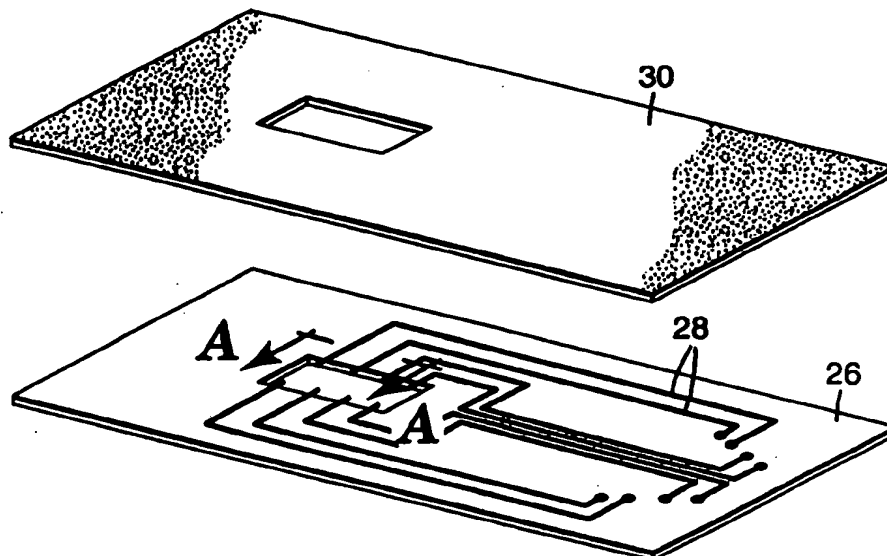


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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>B41J 2/16</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 98/55316</b> <b>(43) International Publication Date:</b> 10 December 1998 (10.12.98)
<b>(21) International Application Number:</b> PCT/US98/10717 <b>(22) International Filing Date:</b> 26 May 1998 (26.05.98) <b>(30) Priority Data:</b> 08/870,162      6 June 1997 (06.06.97)      US <b>(71) Applicant:</b> MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US). <b>(72) Inventors:</b> ROHLOFF, Robert, R.; P.O. Office 33427, Saint Paul, MN 55133-3427 (US). GEORGE, Clayton, A.; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). <b>(74) Agents:</b> SKOLNICK, Steven, E. et al.; Minnesota Mining and Manufacturing Company, Office of Intellectual Property Counsel, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>

**(54) Title:** BONDING SYSTEM IN AN INKJET PRINTER PEN AND METHOD FOR PROVIDING THE SAME**(57) Abstract**

An inkjet printer pen structure is provided that includes a flexible circuit (26) having a plurality of conductors (28) formed on a first surface electrically connected to a plurality of contact pads (29) located on a second surface of the flexible circuit; a body (12) adapted to store and dispense ink; and a bonding system prepared from a latently curable composition located between the first surface of the flexible circuit and the body. The bonding system operably attaches the conductors on the flexible circuit to the body. Also provided is a method for providing such a bonding system in an inkjet printer pen.

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## BONDING SYSTEM IN AN INKJET PRINTER PEN AND METHOD FOR PROVIDING THE SAME

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### BACKGROUND OF THE INVENTION

Generally, an inkjet printer pen includes: (1) a body which includes an ink reservoir and an ink dispensing mechanism which can include various valves, springs, foams, bags and the like which facilitates retention of the ink for handling purposes and dispensing of the ink from the body during a printing operation; (2) a flexible circuit for conducting electrical signals from an inkjet printing machine to a printer chip for volatilization and ejection of ink onto a recording media, usually paper; and (3) a material between the flexible circuit and the body which both firmly attaches the flexible circuit to the body and protects the flexible circuit from unwanted exposure to corrosive printing ink. The printer chip can be in any form and is necessary for actual printing by an inkjet printer pen.

Inkjet printer pens typically include a small metal or plastic ink holding container to which is attached a flexible circuit. This flexible circuit electrically connects the printer chip to the driver electronics in the inkjet printer into which the inkjet pen is placed. The flexible circuit is attached to the printing head in such a way that it conducts the electrical current from the printer machine to the printer chip.

Plastics often used in fabricating inkjet pen bodies include polyphenylene oxide, polysulfone, polyester, liquid crystal polymer (LCP), poly ether-ether-ketone (PEEK), polyetherimide (PEI), phenolics, nylon, and other thermosetting or thermoplastic engineering materials.

The flexible circuit referred to is typically a thin, about 1 mil to about 3 mils (0.025 mm to 0.075 mm) polymer film, e.g., polyimide film, onto which has been fabricated multiple patterns of copper or gold plated copper traces or conductors. For example, a flexible circuit material composed of a polyimide film (UPLIX, commercially available from ICI Composites Inc., Wilmington, DE) of about 0.05 mm in thickness. A plurality of copper traces or electrical conductors

which are also gold plated are formed on a surface of the film. These gold plated copper conductors are typically 0.033 mm in thickness and are typically found only on one side of the polyimide film. However, these conductors may have crossovers through the polyimide film terminating on the opposite side.

5           Inkjet print pens operate by rapidly heating a small volume of ink to cause the ink to vaporize and be ejected through one of a plurality of orifices so as to print a dot of ink on a recording medium, such as a sheet of paper. Typically, the orifices are arranged in one or more linear arrays in a nozzle member. The properly sequenced ejection of ink from each orifice causes characters or other  
10 images to be printed upon the recording medium as the printer chip is moved relative to the medium. The medium is typically shifted each time the printer chip has moved across the medium. The thermal inkjet printer is fast and quiet, as only the ink strikes the recording medium. These printers produce high quality printing and can be made both compact and affordable.

15           To print a single dot of ink, an electrical current from an external power supply of the printer machine is passed through a selected thin film resistor. The resistor is then heated, in turn superheating a thin layer of the adjacent ink within a vaporization chamber, causing explosive vaporization, and consequently, causing ink to be ejected through an associated orifice onto the recording medium.

20           The bonding material used to attach the flexible circuit to the inkjet pen body must have good adhesion to the body and must be strong and robust enough to withstand continuous immersion in the inkjet inks at sometimes elevated temperatures. These inks can be curing, hot-melt (thermoplastic), solvent, aqueous, or a mixture of solvent and aqueous such as alcohol and water. The most  
25 widely used carrier fluids for inks are solvent, aqueous, and a combination thereof. The principal types of ingredients in ink formulations are:

<u>Additive</u>	<u>Purpose</u>
Colorant (dye or pigment)	Marking
Buffer	Stabilize colorant
30 Binder	Improve water and light fastness; fixes pigment to the substrate

	Water or organic solvent	Solvent or Carrier
	Biocide/fungicide	Prevent degradation of ink and clogging of nozzles
	Penetrant	Enhance drying and water fastness
5	Humectant	Prevent drying in nozzles
	Fixing agents	Enhance durability of image
	Surfactants	Improve wetting of the print substrate

Water-based inks used to print on paper are more severely constrained in composition than inks based on organic solvents. For thermal inkjet printing, the ink must be able to withstand high temperatures that are created when ink is vaporized. The pH of the inks can vary from about 4 to about 11 and can be highly corrosive.

The bond between the flexible circuit and the pen body serves two purposes, i.e., to maintain physical contact between the flexible circuit and the printer chip conductors, and to encapsulate the conductors to protect them from contact with the corrosive ink. If the bonding material that is used to bond the flexible circuit to the pen body is attacked by the ink, it can debond and/or result in lifting of the flexible circuit from the pen body allowing ink to contact the conductive circuit causing electrical shorts and other electrical disturbances between those conductors. Also, if the bonding material does not totally encapsulate and protect the circuit from the chemical attack of the ink, electrical shorts or poor signals can occur. Both these problems can render the inkjet printer pen inoperable. During the manufacture of these pens, in some instances it may be preferred that the bonding material is tacky with sufficient initial adhesion to allow the pen to be handled without dislodging the flexible circuitry. Clamping the parts to hold the flexible circuit may not be possible or may add additional steps, cost and time to the manufacturing process.

Some of the bonding methods now used to attach the flexible circuit to the pen bodies are through the use of double sided pressure sensitive adhesive (PSA) tape or through the use of thermoplastic bonding films. While the PSA tapes and thermoplastic films are tacky at room temperature or at elevated temperatures,

neither provides the level of adhesion nor the ink resistance protection required with today's more advanced printing inks which operate at elevated temperatures, contain strong, corrosive solvents or co-solvents and have a pH generally in a range of about 4 to about 11, and typically about 6 to about 8.

5           Curing or thermosetting bonding materials could provide a solution to the shortcomings of both the PSA and non-curing thermoplastic systems mentioned above to provide improved chemically resistant bonds and protective films after cure.

10           However, some curing film technology has the disadvantage of not having adequate handling strength prior to initiation of curing. Also, some cured bonding films typically require a longer cure time than is desired in high speed, high output manufacturing lines typically used for assembling these pens. Many curing chemistries require typically from about 10 minutes to about 90 minutes per unit. Total bonding times in the order of one to four seconds per unit are generally more  
15           often desired. However, other ultraviolet (UV) radiation free radical curing chemistries/technologies which have short cure times, typically about several seconds, are not useful in these inkjet pen applications because the unassembled structure and/or the assembled structure do not allow access of the bonding film to UV curing light. Furthermore, irradiation of the bonding film before the parts are  
20           joined is not possible because the bonding film may cure before the parts are joined together. In free radical curing chemistry types described, curing typically ceases when the exposure to UV light ceases and maintaining exposure to UV radiation throughout the cure cycle may not be possible or practical.

25           Moreover, the bonding films described above are typically formed with a high molecular weight material which is usually not flowable at room temperature and, thus, prevents adequate wetting between the finely spaced leads or conductors (a phenomenon known as "tenting"). Therefore, films using high molecular weight materials do not adequately encapsulate the small, closely spaced conductors and traces from the corrosive character of the inks which, as explained above, leads to  
30           unwanted conductivity between the conductors on the flexible circuit.

Therefore, a bonding system and a method for bonding a flexible circuit to a pen body in an inkjet pen is desired which provides a barrier between conductors on the flexible circuit and the ink in the ink reservoir of the pen body and yet is adaptable to a variety of inkjet pen manufacturing processes.

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### SUMMARY OF THE INVENTION

The present invention provides a bonding system and a method for bonding a flexible circuit to a pen body in an inkjet printer pen. The system and method produce bonds using a bonding system formed from a latently curable composition. As used herein, "latent curable" and "latently curable" mean that the curative of the system is selectively triggered or initiated by exposure to radiation, e.g., ultraviolet (UV) radiation or visible light, which initiates a transition stage, wherein complete cure occurs sometime after exposure to and not necessarily in the presence of the radiation. Preferably, the bonding system is self-fastening.

15

"Self-fastening," as used herein, means that the bonding system may be melt-flowable or pressure sensitive. "Melt-flowable," as used herein, means that the bonding system is substantially tack-free at room temperature and as the composition is heated, it first softens and is conformable and as the bonding system continues to heat, it becomes tacky and wets out sufficiently to bond to a surface.

20

After the bonding system has bonded to a surface, it may remain melt-flowable, i.e., thermoplastic, wherein re-heating will cause it to flow again; it may become thermoset so that it no longer flows when re-heated; or a portion of the bonding system may cure or become cross-linked, i.e., thermoset, while a portion of the bonding system remains thermoplastic. "Pressure sensitive," as used herein, means that the bonding system is aggressively and permanently tacky at room temperature and firmly adheres to a variety of dissimilar surfaces simply by pressing with no more than a pressure equivalent to that exerted by a finger or a hand and typically does not require activation by solvents or heat.

25

In one embodiment of the invention, an inkjet printer pen structure includes a flexible circuit having a plurality of conductors formed on a first surface electrically connected to a plurality of contact pads located on a second surface of

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the flexible circuit; a body adapted to store and dispense ink; and a bonding system prepared from a latently curable composition located between the first surface of the flexible circuit and the body, wherein the bonding system operably attaches the flexible circuit to the body.

5           A bonding system between a flexible circuit and a pen body in an inkjet printer pen according to the present invention provides a number of advantages. The bonding system provides sufficient working or open time after curing is initiated by exposure to radiation which allows for mating of the desired parts. "Open time," as used herein, defines that period of time from the time of initial  
10   exposure of the latently curable composition to radiation to the time when the latently curable composition has sufficiently cured so that a useful bond can no longer be made. During the open time, the latently curable composition continues to cure after the inkjet printer pen components are mated without continued exposure to radiation. Upon completion of curing, sufficient crosslinking and/or  
15   chain extending is formed to prevent ink attack of the conductors of the flexible circuit. The bonding system is also preferably self-fastening so that the bonding system exhibits adhesive properties prior to initiation of cure by exposure to radiation which may decrease the probability of misalignment of the inkjet printer pen parts prior to complete cure. As a result, the bonding systems and methods for  
20   making inkjet printer pens according to the invention are particularly useful in a variety of manufacturing processes where high throughput is required.

          Preferably, the bonding system is formed from a latently curable composition which comprises an epoxy-containing material that contributes to the ultimate strength and resistance (i.e. both chemical and heat resistance) of the  
25   bonding system in an inkjet printer environment. More preferably, the latently curable composition comprises, and more preferably consists of, an epoxy-containing material, a polyester component, an effective amount of a photoinitiator and a hydroxyl-containing material. Additionally, the bonding system is curable at room temperature after initial activation by a photoinitiator.

30           The bonding system is preferably self-fastening which means that it can be pressure sensitive or melt-flowable. In one embodiment, the latently curable



composition is melt-flowable for adaptability in a variety of manufacturing/assembly processes.

In another embodiment, the bonding system is formed from a construction comprising a carrier having a first major surface and a second major surface; a self-  
5 fastening film on the first major surface of the carrier; and the latently curable composition on the second major surface of the carrier. Preferably, the carrier is a film formed from a material that is both thermally stable and chemically stable, more preferably the film comprises a polyester. The self-fastening film comprises a pressure sensitive material or a melt-flowable material.

10 The latently curable composition can be exposed to radiation before or after fastening the composition on the flexible circuit. The latently curable composition can be first fastened to the pen body and then exposed to radiation or it can be first fastened to the flexible circuit. In either instance, the step of fastening can include applying pressure and/or heat to the composition applied to either the inkjet pen  
15 body or the flexible circuit. Additionally, if a transparent pen body is used, the latently curable composition can be applied to either the flexible circuit or the pen body, the remaining part attached to the latently curable composition and the latently curable composition can be exposed to radiation through the transparent pen body. Thus, fastening the latently curable composition to either the pen body  
20 or to the flexible circuit occurs prior to exposure to radiation.

It is preferred that the points of electrical contact between the flexible circuit, the inkjet pen body and areas between adjacent or other electrical conductors on the flexible circuit are encapsulated by the bonding system to prevent ink from shorting the electrical conductors or adjacent conductor together.  
25 Advantageously, the characteristics of the bonding system formed from the latently curable composition allow it to be readily adapted to a wide variety of manufacturing process because continued exposure to radiation and clamping of mated parts prior to cure completion is not required.

These and other features and advantages of the present invention are  
30 discussed further below.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be further understood by reference to the following description and attached drawings which illustrate a preferred embodiment.

5 Fig. 1 is a perspective view of one inkjet printer pen 10.

Fig. 2 is an exploded perspective view of the back surface of a flexible circuit 26 of Fig. 1 with one bonding system 30 according to the present invention bonded thereto.

10 Figs. 3a, 3b, and 3c are partial cross-sections taken along line A--A in Fig. 2 illustrating the bonding of a flexible circuit 26 to a pen body 12 using bonding system 30 according to the present invention.

Fig. 3d is a partial cross-section showing the system 30 of Fig. 3c being bonded to a ink reservoir 12.

15 Fig. 4 is a partial cross-sectional view of another embodiment of the bonding system according to the present invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with this invention, an inkjet printer pen includes a bonding system formed from a latently curable composition that bonds a flexible circuit to  
20 an inkjet pen body. The latently curable composition can cure at room temperature, has sufficient open time to allow for joining of the parts/substrates, and has a curing mechanism that is triggerable by an external influence, such as exposure to radiation, e.g., UV or visible light.

In general, the bonding system is formed from a latently curable  
25 composition that is a polymeric (including oligomeric) composition activated by exposure to radiation to cure. Cure, as used herein, means that the polymers in the composition can become linked between existing or formed polymer chains (crosslink), the polymer chains can extend, thereby increasing in molecular weight, or can both crosslink and extend simultaneously. Once cure has been initiated,  
30 these compositions have an "open time," as defined above. Thus, the latently curable composition continues to cure after the inkjet printer pen components are

5 mated without continued exposure to radiation. Preferably, the open time is about 24 hours or less, more preferably about 6 hours or less, and most preferably about 5 minutes to about 30 minutes. After the open time has passed, the latently curable composition is in a state such that it cannot easily be softened, herein referred to as "complete cure."

10 Preferably, the bonding system is self-fastening. That is, it may be pressure sensitive or melt-flowable. For example, the bonding system can be formed from a latent curable composition that is melt-flowable so that it softens to wet-out the surface(s) on which the bonding system is placed upon the application of heat and/or pressure. When cooled, it bonds two surfaces. The bonding system formed from the latently curable composition that is melt-flowable has good handling properties so that a variety of assembly processes can be used to manufacture inkjet printer pens. Further, the latently curable composition that is melt-flowable has an initial bond strength such that the parts can be fitted together during assembly and prior to cure. For example, some preferred fully cured bonding systems have an overlap shear strength value of greater than or equal to 100 psi (0.69 MPa) and/or 90 degree peel strength value of about 2 to 3 piw (0.35 to 0.53 kN/m) when tested on the materials used to fabricate flexible circuits and inkjet printer pen bodies.

20 Melt-flowable materials used in the bonding system of the invention can be thermoplastic or thermosettable. Melt-flowable materials can be copolymers, graft copolymers, interpenetrating networks, and mixtures thereof.

25 If the bonding system formed from a latently curable composition is melt-flowable, the latently curable composition is preferably positioned on the flexible circuit and heated until it just becomes tacky. Bonding systems formed from compositions which are both latently curable and melt-flowable may be prepared from blends of a thermoplastic polymeric material component and a thermosettable material component, or both. Preferably, the latently curable composition includes a melt-flowable material selected from the group of an epoxy/acrylate, an epoxy/polyester, an epoxy/polycaprolactone, and mixtures thereof.

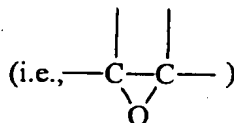
30 In a preferred embodiment, the latently curable compositions useful for the bonding system in the inkjet pen of the invention comprise and, more preferably,

consist essentially of, an epoxy-containing material that contributes to the ultimate strength and resistance (i.e., heat and chemical) of the composition, a polyester component that allows for rapid green strength build-up, a photoinitiator that permits the composition to cure upon exposure to radiation and a hydroxyl-  
 5 containing material to retard the rate of curing and/or impart flexibility to the latently curable compositions. This bonding system possesses improved physical properties such as improved heat resistance, and improved chemical resistance in an inkjet printer environment.

One example of a latent curable, melt-flowable composition is an  
 10 epoxy/polyester hotmelt composition, described in European Patent Publication 0 620 259 (George et al.). This composition may latently cure on exposure to radiation to provide high strength materials having good adhesion to the pen body substrate. In this composition, the epoxy-containing material is the thermosettable component and the polyester is the thermoplastic polymeric material. For  
 15 example, when the radiation used is UV, it is typically in the 200-800 nanometer range and the radiation level is from about 50 millijoules to about 1000 millijoules. Preferably, the latently curable composition includes a hydroxyl-containing material to impart flexibility and toughness to the latently curable compositions. Preferred polyesters for the epoxy/polyester material are solid at room temperature  
 20 and have a number average equivalent weight of about 7500 to about 200,000, more preferably from about 10,000 to about 50,000, and most preferably, from about 15,000 to about 30,000.

#### Epoxy-Containing Materials

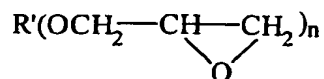
25 Epoxy-containing materials useful in the compositions of the invention are any organic compounds having at least one oxirane ring



polymerizable by a ring opening reaction. Such materials, broadly called epoxides, include both monomeric and polymeric epoxides and can be aliphatic, cycloaliphatic, or aromatic. These materials generally have, on the average, at least two epoxy groups per molecule (preferably more than two epoxy groups per molecule). The polymeric epoxides include linear polymers having terminal epoxy groups (e.g., a diglycidyl ether of a polyoxyalkylene glycol), polymers having skeletal oxirane units (e.g., polybutadiene polyepoxide), and polymers having pendent epoxy groups (e.g., a glycidyl methacrylate polymer or copolymer). The weight average molecular weight of the epoxy-containing material may vary from 58 to about 100,000 or more. Mixtures of various epoxy-containing materials can also be used in the latently curable compositions of the invention. The "average" number of epoxy groups per molecule is defined as the number of epoxy groups in the epoxy-containing material divided by the total number of epoxy molecules present.

Useful epoxy-containing materials include those which contain cyclohexene oxide groups such as the epoxycyclohexanecarboxylates, typified by 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexanecarboxylate, 3,4-epoxy-2-methylcyclohexylmethyl-3,4-epoxy-2-methylcyclohexane carboxylate, and bis(3,4-epoxy-6-methylcyclohexylmethyl) adipate. For a more detailed list of useful epoxides of this nature, reference may be made to U.S. Pat. No. 3,117,099.

Further epoxy-containing materials which are particularly useful in the practice of this invention include glycidyl ether monomers of the formula



where R' is alkyl or aryl and n is an integer of 1 to 6. Examples are the glycidyl ethers of polyhydric phenols obtained by reacting a polyhydric phenol with an excess of chlorohydrin such as epichlorohydrin (e.g., the diglycidyl ether of 2,2-bis-(2,3-epoxypropoxyphenol) propane). Further examples of epoxides of this type

which can be used in the practice of this invention are described in U.S. Pat. No. 3,018,262.

There is a host of commercially available epoxy-containing materials which can be used in this invention. In particular, epoxides which are readily available include octadecylene oxide, epichlorohydrin, styrene oxide, vinyl cyclohexene oxide, glycidol, glycidylmethacrylate, diglycidyl ether of Bisphenol A (e.g., those available under the trade designations EPON 828, EPON 1004, and EPON 1001F from Shell Chemical Co., and DER-332 and DER-334, from Dow Chemical Co.), diglycidyl ether of Bisphenol F (e.g., ARALDITE GY281 from Ciba-Geigy), vinylcyclohexene dioxide (e.g., ERL 4206 from Union Carbide Corp.), 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexene carboxylate (e.g., ERL-4221 from Union Carbide Corp.), 2-(3,4-epoxycyclohexyl-5,5-spiro-3,4-epoxy) cyclohexane-metadioxane (e.g., ERL-4234 from Union Carbide Corp.), bis(3,4-epoxycyclohexyl) adipate (e.g., ERL-4299 from Union Carbide Corp.), dipentene dioxide (e.g., ERL-4269 from Union Carbide Corp.), epoxidized polybutadiene (e.g., OXIRON 2001 from FMC Corp.), silicone resin containing epoxy functionality, epoxy silanes (e.g., beta-(3,4-epoxycyclohexyl)ethyltrimethoxy silane and gamma-glycidoxypropyltrimethoxy silane, commercially available from Union Carbide), flame retardant epoxy resins (e.g., DER-542, a brominated bisphenol type epoxy resin available from Dow Chemical Co.), 1,4-butanediol diglycidyl ether (e.g., ARALDITE RD-2 from Ciba-Geigy), hydrogenated bisphenol A-epichlorohydrin based epoxy resins (e.g. EPONEX 1510 from Shell Chemical Co.), and polyglycidyl ether of phenolformaldehyde novolak (e.g., DEN-431 and DEN-438 from Dow Chemical Co.).

25

### Polyesters

Useful polyesters include both hydroxyl and carboxyl terminated materials, which may be amorphous or semicrystalline. Hydroxyl terminated materials are

preferred. By "amorphous" is meant a material that displays a glass transition temperature but does not display a measurable crystalline melting point by differential scanning calorimetry (DSC). Preferably the glass transition temperature is less than the decomposition temperature of the photoinitiator  
5 (discussed below), but without being more than about 120°C. By "semicrystalline" is meant a polyester component that displays a crystalline melting point by DSC, preferably with a maximum melting point of about 150°C.

In general, if it is desired for the latently curable composition to cure under ambient conditions, the polyester component should have a glass transition  
10 temperature less than the ambient temperature, preferably less than about 20°C. As the glass transition temperature of the polyester component increases, it may be necessary to both thermally and radiation cure the composition.

The polyester preferably has a Brookfield viscosity which exceeds 10,000 millipascals at 121°C. Viscosity is related to the equivalent weight of the polyester  
15 component. Preferred polyester components also have a number average equivalent weight of about 7500 to 200,000, more preferably from about 10,000 to 50,000 and most preferably from about 15,000 to 30,000.

Polyester components useful in the invention comprise the reaction product of dicarboxylic acids (or their diester equivalents) and diols. The diacids (or their  
20 diester equivalents) can be saturated aliphatic acids containing from 4 to 12 carbon atoms (including unbranched, branched, or cyclic materials having 5 to 6 atoms in a ring) and/or aromatic acids containing from 8 to 15 carbon atoms. Examples of suitable aliphatic acids are succinic, glutaric, adipic, pimelic, suberic, azelaic, sebacic, 1,12 dodecanedioic, 1,4-cyclohexanedicarboxylic, 1,3-  
25 cyclopentanedicarboxylic, 2-methylsuccinic, 2-methylpentanedioic, 3-methylhexanedioic acids and the like. Suitable aromatic acids include terephthalic acid, isophthalic acid, phthalic acid, 4,4'-benzophenone dicarboxylic acid, 4,4'-diphenylmethanedicarboxylic acid, 4,4'-diphenylether dicarboxylic acid, 4,4'-

diphenylthioether dicarboxylic acid and 4,4'-diphenylamine dicarboxylic acid.

Preferably the structure between the two carboxyl groups in these diacids contains only carbon and hydrogen; more preferably it is a phenylene group. Blends of any of the foregoing diacids may be used.

5           The diols include branched, unbranched, and cyclic aliphatic diols having from 2 to 12 carbon atoms, such as, for example, ethylene glycol, 1,3-propylene glycol, 1,2-propylene glycol, 1,4-butanediol, 1,3-butanediol, 1,5-pentanediol, 2-methyl-2,4-pentanediol, 1,6-hexanediol, 1,8-octanediol, cyclobutane-1,3-di(2'ethanol), cyclohexane-1,4-dimethanol, 1,10-decanediol, 1,12-dodecanediol,  
10       and neopentyl glycol. Long chain diols including poly(oxyalkylene) glycols in which the alkylene group contains from 2 to 9 carbon atoms (preferably 2 to 4 carbon atoms) may also be used. Blends of any of the foregoing diols may be used.

          Useful, commercially available hydroxyl terminated polyester materials  
15       include various saturated, linear, semicrystalline copolyesters available from Huls America, Inc. such as DYNAPOL S1358, DYNAPOL S1227, DYNAPOL S1229, DYNAPOL S1401, DYNAPOL S1228, and DYNAPOL S1402. Useful saturated, linear amorphous copolyesters available from Huls America, Inc. include DYNAPOL S1313, DYNAPOL 1421 and DYNAPOL S1420.

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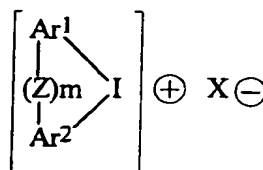
#### Photoinitiators

          The photoinitiators which are useful in the compositions of the invention are cationic and include these three types, viz. aromatic iodonium complex salts, aromatic sulfonium complex salts and metallocene salts. Useful aromatic  
25       iodonium complex salts are described more fully in U.S. Patent No. 4,256,828. Preferred aromatic iodonium complex salts are diaryliodonium hexafluorophosphate and diaryliodonium hexafluoroantimonate. Useful aromatic sulfonium complex salts are described more fully in U.S. Patent No. 4,256,828. Preferred aromatic sulfonium complex salts are triaryl-substituted salts such as

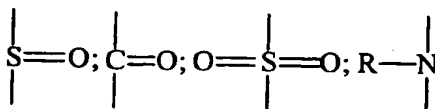


triphenylsulfonium hexafluoroantimonate. Useful metallocene salts are described more fully in U. S. Patent No. 5,089,536. An example of a useful salt is  $\text{Cp}(\text{xylenes})\text{Fe}+\text{SbF}_6^-$ . The metallocene salts can be activated by black light or visible light. The sulfonium salts can be activated by exposure to medium pressure  
 5 mercury UV light. In either instance, the epoxy can cure through heat.

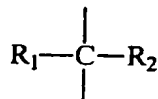
Useful aromatic iodonium complex salts have the formula:



where  $\text{Ar}^1$  and  $\text{Ar}^2$  are aromatic groups having 4 to 20 carbon atoms and are  
 10 selected from the group consisting of phenyl, thienyl, furanyl and pyrazolyl groups.  
 $\text{Z}$  is selected from the group consisting of oxygen; sulfur;



where  $\text{R}$  is aryl (of 6 to 20 carbons, such as phenyl) or acyl (of 2 to 20 carbons,  
 15 such as acetyl, benzoyl, etc.); a carbon-to-carbon bond; or



where  $\text{R}_1$  and  $\text{R}_2$  are selected from hydrogen, alkyl radicals of 1 to 4 carbons, and  
 20 alkenyl radicals of 2 to 4 carbons. The value of  $m$  is zero or 1 and  $\text{X}$  is a halogen-  
 containing complex anion selected from tetrafluoroborate, hexafluorophosphate,  
 pentafluorohydroxyantimonate, hexafluoroarsenate, and hexafluoroantimonate.

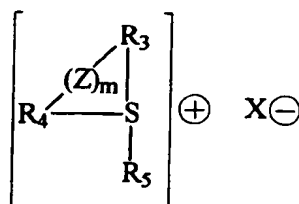
The  $\text{Ar}^1$  and  $\text{Ar}^2$  aromatic groups may optionally have one or more fused  
 benzo rings (e.g., naphthyl, benzothienyl, dibenzothienyl, benzofuranyl,  
 25 dibenzofuranyl, etc.). The aromatic groups may also be substituted, if desired, by

one or more non-basic groups if they are essentially non-reactive with epoxide and hydroxyl functionalities.

Useful aromatic iodonium complex salts are described more fully in U.S. Pat. No. 4,256,828. The preferred aromatic iodonium complex salts are  
 5 diaryliodonium hexafluorophosphate and diaryliodonium hexafluoroantimonate.

The aromatic iodonium complex salts useful in the compositions of the invention are photosensitive only in the ultraviolet region of the spectrum. They, however, can be sensitized to the near ultraviolet and the visible range of the spectrum by sensitizers for known photolyzable organic halogen compounds.  
 10 Illustrative sensitizers include aromatic amines and colored aromatic polycyclic hydrocarbons.

Aromatic sulfonium complex salt photoinitiators suitable for use in the compositions of the invention can be defined by the formula



15 wherein R<sub>3</sub>, R<sub>4</sub> and R<sub>5</sub> can be the same or different, provided that at least one of the groups is aromatic. These groups can be selected from aromatic moieties having 4 to 20 carbon atoms (e.g., substituted and unsubstituted phenyl, thienyl, and furanyl) and alkyl radicals having 1 to 20 carbon atoms. The term "alkyl" includes  
 20 substituted alkyl radicals (for example, substituents such as halogen, hydroxy, alkoxy, aryl). Preferably, R<sub>3</sub>, R<sub>4</sub> and R<sub>5</sub> are each aromatic. Z, m and X are all as defined above with regard to the iodonium complex salts.

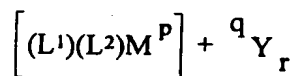
If R<sub>3</sub>, R<sub>4</sub> or R<sub>5</sub> is an aromatic group, it may optionally have one or more fused benzo rings (e.g., naphthyl, benzothienyl, dibenzothienyl, benzofuranyl,  
 25 dibenzofuranyl, etc.) Such aromatic groups may also be substituted, if desired, by

one or more non-basic groups that are essentially non-reactive with epoxide and hydroxyl functionality.

The triaryl-substituted salts such as triphenylsulfonium hexafluoroantimonate are preferred. Useful sulfonium complex salts are described more fully in U.S. Pat. No. 4,256,828.

The aromatic sulfonium complex salts useful in the invention are inherently photosensitive only in the ultraviolet region of the spectrum. They, however, are sensitized to the near ultraviolet and the visible range of the spectrum by a select group of sensitizers such as described in U.S. Pat. No. 4,256,828.

Useful metallocene salts can have the formula:



wherein

$M^P$  represents a metal selected from Cr, Mo, W, Mn, Re, Fe, and Co;

$L^1$  represents 1 or 2 ligands contributing  $\pi$ -electrons that can be the same or different ligand selected from substituted and unsubstituted  $\eta^3$ -allyl,  $\eta^5$ -cyclopentadienyl, and  $\eta^7$ -cycloheptatrienyl and  $\eta^6$ -aromatic compounds selected from  $\eta^6$ -benzene and substituted  $\eta^6$ -benzene compounds and compounds having 2 to 4 fused rings each capable of contributing 3 to 8  $\pi$ -electrons to the valence shell of  $M^P$ ;

$L^2$  represents none or 1 to 3 ligands contributing an even number of sigma-electrons that can be the same or different ligand selected from carbon monoxide or nitrosonium;

with the proviso that the total electronic charge contributed to  $M^P$  by  $L^1$  and  $L^2$  plus the ionic charge on the metal  $M^P$  results in a net residual positive charge of  $q$  to the complex, and

$q$  is an integer having a value of 1 or 2, the residual electrical charge of the complex cation;

Y is a halogen-containing complex anion selected from  $\text{AsF}_6^-$ ,  $\text{SbF}_6^-$  and  $\text{SbF}_6\text{OH}^-$ ; and

r is an integer having a value of 1 or 2, the numbers of complex anions required to neutralize the charge q on the complex cation.

5 Useful metallocene salts are described more fully in U.S. Pat. No. 5,089,536. The metallocene salts may be used in conjunction with a reaction accelerator such as an oxalate ester of a tertiary alcohol.

Useful commercially available photoinitiators include FX-512, an aromatic sulfonium complex salt (Minnesota Mining and Manufacturing Co.; St. Paul, MN),  
10 UVI-6974, an aromatic sulfonium complex salt (Union Carbide Corp.), IRGACURE 261, a metallocene complex salt (Ciba-Geigy), CD-1010, CD-1011 and CD-1012, cationic photoinitiators (all available from Sartomer). Preferably, the photoinitiator is cationic, more preferably, triaryl sulfonium hexafluoroantimonate 50% by weight in polypropylene carbonate (CD-1010 from  
15 Sartomer).

#### Hydroxyl-Containing Materials

Preferably, the latently curable compositions further comprise a hydroxyl-containing material. The hydroxyl-containing material may be any liquid or solid  
20 organic material having hydroxyl functionality of at least 1, preferably at least 2, and most preferably about 3. The hydroxyl-containing organic material should be free of other "active hydrogen" containing groups such as amino and mercapto moieties. The hydroxyl-containing organic material should also be substantially free of groups which may be thermally or photolytically unstable so that the  
25 material will not decompose or liberate volatile components at temperatures below about 100°C or when exposed to actinic radiation during curing. Preferably the organic material contains two or more primary or secondary aliphatic hydroxyl groups (i.e., the hydroxyl group is bonded directly to a non-aromatic carbon atom).

The hydroxyl group may be terminally situated, or may be pendent from a polymer or copolymer. The number average equivalent weight of the hydroxyl-containing material is preferably about 31 to 2250, more preferably about 80 to 1000, and most preferably about 80 to 350.

5        Representative examples of suitable organic materials having a hydroxyl functionality of 1 include alkanols, monoalkyl ethers of polyoxyalkylene glycols, and monoalkyl ethers of alkylene glycols.

      Representative examples of useful monomeric polyhydroxy organic materials include alkylene glycols (e.g., 1,2-ethanediol, 1,3-propanediol, 1,4-  
10    butanediol, 2-ethyl-1,6-hexanediol, bis(hydroxymethyl)cyclohexane, 1,18-dihydroxyoctadecane, and 3-chloro-1,2-propanediol), polyhydroxyalkanes (e.g., glycerine, trimethylolthane, pentaerythritol, and sorbitol) and other polyhydroxy compounds such as N,N-bis(hydroxyethyl)benzamide, 2-butene-1,4-diol, castor oil, etc.

15       Representative examples of useful polymeric hydroxyl-containing materials include polyoxyalkylene polyols (e.g., polyoxyethylene and polyoxypropylene glycols and triols of equivalent weight of 31 to 2250 for the diols or 80 to 350 for triols), polytetramethylene oxide glycols of varying molecular weight, hydroxyl-terminated polyesters, and hydroxyl-terminated polylactones.

20       Useful commercially available hydroxyl-containing materials include the POLYMEG series (available from QO Chemicals, Inc., West Lafayette, IN) of polytetramethylene oxide glycols such as POLYMEG 650, 1000 and 2000; the TERATHANE series (from E.I. duPont de Nemours and Company, Wilmington, DE) of polytetramethylene oxide glycols such as TERATHANE 650, 1000 and  
25    2000; POLYTHF, a polytetramethylene oxide glycol from BASF Corp.; the BUTVAR series (available from Monsanto Chemical Company, St. Louis, MO) of polyvinylacetal resins such as BUTVAR B-72A, B-73, B-76, B-90 and B-98; the TONE series (available from Union Carbide Corp., Danbury, CT) of

polycaprolactone polyols such as TONE 0200, 0210, 0230, 0240, and 0260; the DESMOPHEN series (available from Miles Inc., Pittsburgh, PA) of saturated polyester polyols such as DESMOPHEN 2000, 2500, 2501, 2001KS, 2502, 2505, 1700, 1800, and 2504; the RUCOFLEX series (available from Ruco Corp.,  
5 Hicksville, NY) of saturated polyester polyols such as S-107, S-109, S-1011 and S-1014; VORANOL 234-630 (a trimethylol propane) from Dow Chemical Company, Midland, MI; VORANOL 230-238 (a glycerol polypropylene oxide adduct) from Dow Chemical Company; the SYNFAC series (from Milliken Chemical, Spartanberg, SC) of polyoxyalkylated bisphenol A's such as SYNFAC 8009,  
10 773240, 8024, 8027, 8026, and 8031; and the ARCOL series (from Arco Chemical Co., Newtown Square, PA) of polyoxypropylene polyols such as ARCOL 425, 1025, 2025, 42, 112, 168, and 240.

The amount of hydroxyl-containing organic material used in the compositions of the invention may vary over a broad range, depending on factors  
15 such as the compatibility of the hydroxyl-containing material with both the epoxy-containing material and the polyester component, the equivalent weight and functionality of the hydroxyl-containing material, and the physical properties desired in the final cured composition.

The hydroxyl-containing material is particularly useful in tailoring the  
20 flexibility of the latently curable compositions useful in the invention. As the equivalent weight of the hydroxyl-containing material increases, the flexibility of the latently curable composition correspondingly increases although there may be a consequent loss in cohesive strength. Similarly, decreasing equivalent weight may result in a loss of flexibility with a consequent increase in cohesive strength. Thus,  
25 the equivalent weight of the hydroxyl-containing material is selected so as to balance these two properties, the appropriate balance depending on the particular application. For example, to tailor the flexibility of the bonding system, the latently curable composition preferably includes polyoxyethylene glycols and

triols having an equivalent weight of about 31 to 2250 for the glycols and 80 to 350 for the triols. Even more preferred are polyoxypropylene glycols and triols having an equivalent weight of about 31 to 2250 for the glycols and an equivalent weight of about 80 to 350 for the triols.

5           The incorporation of polyether polyols into the latently curable compositions useful in the bonding systems in the inkjet printer pens of the invention is especially desirable for adjusting the rate at which the compositions cure upon exposure to radiation. Increasing amounts of a polyether polyol can retard the curing reaction for a time sufficient to allow the bonding of substrates  
10   that are not radiation transparent. The effect is more pronounced when the polyester component has a glass transition temperature below about 20°C.

          Useful polyether polyols (i.e., polyoxyalkylene polyols) for adjusting the rate of cure include polyoxyethylene and polyoxypropylene glycols and triols having a hydroxyl equivalent weight of about 31 to 2250 for the diols and about 80  
15   to 350 for the triols, as well as polytetramethylene oxide glycols of varying weight average molecular weight and polyoxyalkylated bisphenol A's. Preferred hydroxyl-containing materials are glycerol polypropylene oxide adducts, such as VORANOL 230-238 commercially available from Dow Chemical Company.

#### 20   Additives

          Additives may also be included in the latently curable composition of the present invention. Optionally, up to 50% of the total weight of the composition (based on the epoxy-containing material, the polyester component, the photoinitiator and the optional hydroxyl-containing material), may include  
25   additives selected from the group of a tackifier, a filler, an adjuvant, an adhesion enhancer, a plasticizer, a compatibilizer, and mixtures thereof. Fillers, such as silica, glass, clay, talc, pigments, colorants, glass or polymeric expanded or unexpanded beads or bubbles, glass or ceramic fibers, and the like may be included

so as to reduce the weight or cost of the composition. Additives may be added to adjust viscosity, and provide additional reinforcement. Tackifiers such as rosins (e.g., gum rosin, tall oil rosin, wood rosin), modified rosins (e.g., polymerized rosin, hydrogenated rosin, disproportionated rosin), rosin esters, hydrocarbon  
5 resins, polymerized terpenes, pure monomer resins, hydrogenated hydrocarbons, and reinforcing resins may be added to the latent curable composition to enhance self-fastening properties. One preferred tackifier is a terpene phenol copolymer, available under the trade name ARAKAWA 2130 from Arakawa Chemical Industries, Ltd., Chicago, IL. Preferred additives and amounts of additives are  
10 those that do not adversely affect the curing process.

The latently curable compositions comprise from 2 parts to 95 parts by weight per 100 parts by weight total of the epoxy-containing material and, correspondingly, from 98 parts to 5 parts by weight of the polyester component. More preferably, the latently curable compositions of the invention comprise from  
15 2 parts to 80 parts by weight of the epoxy-containing material and, correspondingly, from 98 parts to 20 parts by weight of the polyester component. Most preferably, the latently curable compositions of the invention comprise from 2 parts to 60 parts by weight of the epoxy-containing material, and, correspondingly, from 98 parts to 40 parts by weight of the polyester component.  
20 Increasing amounts of the epoxy-containing material relative to the polyester component generally result in latently curable compositions having higher ultimate strength and heat resistance but less flexibility, less green strength build-up, and lower viscosity. Increasing amounts of the polyester component generally result in latently curable compositions having lower ultimate strength, e.g., shear or peel  
25 adhesion, heat resistance and higher viscosity but greater flexibility and green strength build-up. Thus, the relative amounts of these two ingredients are balanced depending on the properties sought in the final composition.



The photoinitiator is included in an amount ranging from about 0.1 to 4% by weight based on the combined weight of the epoxy-containing material and the polyester component. Increasing amounts of the photoinitiator can result in an accelerated curing rate but may require that the latently curable composition be applied in a thinner layer so as to avoid curing only at the surface. Increased amounts of photoinitiator can also result in reduced energy exposure requirements. The amount of the photoinitiator is determined by the desired rate at which the composition should cure, the intensity of the radiation source, and the thickness of the composition.

The relative amount of the hydroxyl-containing organic material in the composition is determined by the ratio of the number of hydroxyl groups to the number of epoxy groups in the latently curable composition. That ratio may range from about 0:1 to about 1:1, more preferably from about 0.1:1 to about 0.8:1, and most preferably about 0.1:1 to about 0.7:1 of the number of hydroxyl groups to epoxy groups. Larger amounts of the hydroxyl-containing material increase the flexibility of the latently curable composition but with a consequent loss of cohesive strength. If the hydroxyl containing material is a polyether polyol, increasing amounts will further slow the curing process.

#### Method for Making a Bonding System

The latently curable compositions of the invention are prepared by mixing the various ingredients in a suitable vessel, preferably one that is not transparent to actinic radiation, at an elevated temperature sufficient to liquefy the components so that they can be efficiently mixed with stirring until the components are thoroughly melt blended but without thermally degrading the materials. The components may be added simultaneously or sequentially, although it is preferred to first blend the epoxy-containing material and the polyester component followed by the addition of the hydroxyl-containing material, any additives, and then the photoinitiator.

An exemplary method of making a latently curable composition includes placing the solid and liquid epoxy-containing materials and the solid polyester resin(s) into a metal container and melting them into a viscous liquid at about 280-320°F (138-160°C). This can be done using a hot plate, oven, or other type of heated vessel. To this heated mixture is added a tackifier. Then a hydroxyl-containing material and a wax (such as a microcrystalline polypropylene wax, used as a nucleating agent, available under the trade designations UNILIN 700 and UNILIN 550, both commercially available from Petrolite, Tulsa, OK) are added and mixed into the heated mixture until a uniform mixture results. Once a uniform mixture results, the photoinitiator is added and mixed in by stirring. The heated latently curable composition is then coated into a film or is cooled to room temperature and coated at a later time. During the mixing above, the heated latently curable composition should be kept out of direct UV lighting as much as possible to prevent premature activation of the curing system. This is typically accomplished by extinguishing the overhead lighting in the hood and/or room and by shielding the mixing vessel from unwanted exposure to radiation.

In one method, the latently curable composition, as described above, is heated to 350-400°F (177-205°C). Preferably, the latently curable composition is in the form of a film and any one of several methods for coating the molten composition into a film can be used. These include die-slot extrusion, hot-bar or hot knife coating or hot coating rod methods. The preferred method used to coat these films involves using the hot-bar method. Basically, this involves a heated metal bar positioned over a heated metal bed in such a manner as to provide a controlled orifice of about 8 to 10 mils (0.20 mm to 0.25 mm). Through this orifice or slot is placed a length of a thin carrier, such as paper or plastic, onto which the latently curable composition will be coated. Once this thin carrier, typically 3 mils (0.075 mm) to 5 mils (0.13 mm) in thickness, is placed in the slot between the heated bar and the bed, a remaining 5 mils (0.13 mm) opening will result. This remaining 5 mils (0.13 mm) opening will provide the space for coating a 5 mils (0.13 mm) thick film of the latently curable composition. The actual coating involves placing or pouring the molten latently curable composition onto the

carrier and pulling that paper or plastic carrier through the hot bar/hot bed orifice which results in a 5 mils (0.13 mm) coating of latently curable composition onto the carrier. The rate of pulling should be about 3 to 4 feet (0.9 m to 1.2 m) per minute which typically gives a smooth, uniform hot coating onto the carrier. In  
5 about 5-15 seconds, the 5 mils (0.13 mm) latently curable composition film will cool to near room temperature upon which the molten latently curable composition converts to a substantially tack-free film.

If the carrier upon which the adhesive is coated is silicone treated paper or plastic film, then the cooled latently curable composition film can be removed and  
10 used as an unsupported film for bonding two surfaces together. If the carrier onto which the latently curable composition is coated is a non-release coated surface, such as a polyester film, then the latently curable composition film cannot be removed and the resulting combination of latently curable composition and polyester film could be used in a bonding system. This single side coated carrier  
15 can be additionally processed to put a self-fastening material on the carrier surface opposite the latently curable composition. The self-fastening material can be pressure sensitive or melt-flowable and when melt-flowable, it can be non-latent curable or it can be latently curable like the other side. Thus, the resulting bonding system having a three layer construction can be used to bond two surfaces together.

20 If the bonding system formed from a latently curable composition is also melt-flowable, the method of the invention includes placing a melt-flowable latently curable composition over a pen body substrate and heating the composition to cause sufficient softening so that it bonds to the substrate. As the composition is heated, it first softens and conforms to the surface of the substrate, thereby  
25 allowing trapped air to be pushed out by the flowing material. Further into the heating cycle, as the composition becomes hotter, it becomes tacky, and wets out sufficiently on the surface to bond to the surface. In some applications, the composition will also melt and flow to conceal defects, surface imperfections, and/or fill in gaps. However, if the melt-flowable latently curable composition is  
30 placed on the substrate at room temperature, it is preferably tack-free.

It is preferred that the bonding system formed from a latently curable composition be substantially non-tacky at ambient temperatures for reasons of machine handability. If, however, the bonding system is pressure sensitive or tacky at room temperature, the bonding system may be protected by a release liner  
5 or liners from dust and other contaminants prior to use and to provide transportability through high speed assembly equipment. However, at least one release liner is highly desirable for either composition in most manufacturing processes to provide a carrier for the latently curable composition.

The total thickness of a bonding system (including a layered construction  
10 described above) prior to curing typically is about 0.5 mils (0.013 mm) to about 40 mils (1.0 mm), preferably about 2 mils (0.05 mm) to about 5 mils (0.13 mm) in thickness. Bonding systems can be prepared in continuous lengths creating rolls up to several thousand feet (609 m) in length and 12 inches (300 mm) to 72 inches (1800 mm) wide if so desired. Again, all preparation of the bonding system should  
15 be done in such a manner to substantially minimize the exposure to UV or UV containing radiation so as to prevent activation of the photoinitiator, resulting in premature curing of the latently curable composition. Typically, about 1 hour exposure to indirect fluorescent lighting is safe and will not activate the photoinitiator. Preferably, the coated sheets or rolls as described above should be  
20 stored in a cool, dark location prior to bonding.

#### Substrate Bonding

Typically, the latently curable composition is applied to a single substrate, such as a flexible circuit or an inkjet pen body, and once so applied is exposed to a  
25 radiation source to initiate the curing of the epoxy-containing material. While not wishing to be bound by any particular theory, the epoxy-containing material is believed to cure or crosslink with itself, the hydroxyl-containing material, and, perhaps, to some degree with the polyester component. Preferably, the latently curable composition is first applied to a flexible circuit.

Preferably, bonding a flexible circuit to a pen body is accomplished by attaching a film of the latently curable composition to the flexible circuit on a surface having a plurality of conductors (i.e., the gold plated, copper trace side). This can be done by cutting the film of the latently curable composition to the exact shape desired and placing this shaped film onto the flexible circuit. A heated shoe is then pressed onto the film, melting the latently curable composition so that it flows between the traces and conductors and bonds to the flexible circuit surface. The latently curable composition covers and protects the entire flexible circuit surface. A release coating of silicone under the trade designation, TEFLON, or silicone rubber or paper is typically placed between the heated shoe or thermode and the latently curable composition film to prevent molten latently curable composition from sticking or bonding to the heated shoe which is undesirable. A typical bonding temperature used to bond the latently curable composition is about 180°F to about 320°F (about 82°C to about 160°C). Pressure would be typically about 5 to about 20 pounds per square inch (about 34.5 kPa to 138 kPa) of bonding area and dwell time (the time the hot shoe remains in contact with the latently curable composition) is about 3 to about 5 seconds. Of course, the hot shoe temperature can be higher but then a shorter contact/bond time would be used. The proper temperature, pressure, and time conditions would be determined by the optimum properties and flow characteristics desired in the final bond.

The latently curable composition serves to protect as well as to bond. In a protective function, the latently curable composition protects the fragile conductors from external attack of inks, humidity, conductive shorting, and other unwanted outside influences to these gold-plated copper electrical conductors.

Curing of the latently curable composition begins upon exposure of the composition to any source emitting, preferably, actinic radiation (i.e., radiation having a wavelength in the ultraviolet or visible spectral regions) and continues for a period of time thereafter. Suitable sources of radiation include mercury, xenon, carbon arc, tungsten filament lamps, sunlight, etc. Ultraviolet radiation, especially from a medium pressure mercury arc lamp, is most preferred. Exposure times may

be from less than about 1 second to 10 minutes or more (to provide a total energy exposure of about 0.2 Joules/square centimeter ( $J/cm^2$ )) depending upon both the amount and the type of reactants involved, the radiation source, the distance from the radiation source, and the thickness of the composition to be cured.

5       The compositions may also be cured by exposure to electron beam radiation. The dosage necessary is generally from less than 1 megarad to 100 megarads or more. The rate of curing tends to increase with increasing amounts of photoinitiator at a given light exposure or irradiation. The rate of curing also increases with increased radiation intensity or electron dosage.

10       Latently curable compositions including a hydroxyl-containing material that retards the curing rate are particularly desirable when bonding together two substrates that are not transparent to the radiation. After applying the latently curable composition to the pen body and irradiating the composition, the second substrate, e.g., the flexible circuit, may be bonded to the first substrate by the  
15       latently curable composition at any time during the open time until the latently curable composition has sufficiently cured so that it cannot be bonded to a substrate. Preferably, the second substrate is applied to the latently curable composition within the open time, preferably within about 24 hours, more preferably within about 8 hours, and most preferably, within about 5 minutes to  
20       about 30 minutes from the time of exposure of the latently curable composition to radiation. That is, for a period of time (the open time) after the composition has been irradiated, it remains sufficiently uncured such that a second substrate can be bonded thereto. (A similar effect may also be achieved through the use of a high glass transition temperature polyester component, e.g., a glass transition  
25       temperature above 20°C).

      The second substrate, e.g., the pen body, is typically bonded using heat, pressure or both heat and pressure, (for example, with a heated press, heated nip rollers, or a heated laminator). Typical conditions for applying the pen body

includes a press time of about 1 second to about 5 seconds at a temperature of about 250°F to about 300°F (about 121°C to about 149°C) with or without applying a pressure of about 5 piw to about 25 piw (about 0.88 kN/m to about 4.4 kN/m). Laminator pressures of about 200 kiloPascals (kPa) or more are useful. In  
5 another approach, a free standing film may be irradiated on one or both sides and then placed between two substrates followed by the use of heat, pressure or both heat and pressure to bond the film to the two substrates. Alternatively, two substrates may be bonded together if one of the substrates is transparent to the radiation, thereby permitting the latently curable composition to be irradiated  
10 through the transparent substrate.

Once the latently curable composition is exposed to radiation, the curing process is initiated. Subsequent to radiation exposure the latently curable compositions can be tack-free, or can be tacky for a limited period of time but eventually achieving a tack-free condition. Preferably, full or complete cure may  
15 be achieved under ambient conditions in about 48 hours or less, and more preferably about 24 hours or less, depending upon the intensity of the radiation source, the radiation exposure time, the concentration of the photoinitiator, and the concentration of the hydroxyl-containing component which are included in the latently curable composition. When curing under only ambient conditions is  
20 desired, the glass transition temperature of the polyester component should be less than the ambient temperature, preferably less than about 20°C.

The time to reach full cure may be accelerated by post curing the compositions with heat, such as in an oven. The time and temperature of the post cure will vary depending upon the glass transition temperature of the polyester  
25 component, the concentration of the photoinitiator, the radiation exposure conditions, and the like. Typical post cure conditions range from 5 to 15 minutes at about 50°C to about 1 to 2 minutes at temperatures up to about 100°C. An accelerated cure can also be achieved by applying heat and pressure to bond two substrates together such as when using a heated press, a heated laminator or heated

nip rollers. For those latently curable compositions based on a polyester component having a glass transition temperature above about 20°C, the use of heat in addition to radiation to cure the composition is recommended.

Referring to Fig. 1 reference numeral 10 generally indicates an inkjet print pen incorporating one embodiment of the present invention. Inkjet print pen 10 includes a pen body 12, a printer chip 20, formed, for example, using Tape Automated Bonding (TAB), and a flexible circuit 26.

The particular structure of the printer chip 20 is not important in this application, and various types of printer chips, such as those with a nickel nozzle plate, may also be used with the present invention.

One surface (or front surface) of the flexible circuit 26 includes a plurality of contact pads 29. Printer pen 10 is designed to be installed in a printer (not shown) so that the contact pads 29, on the front surface of the flexible circuit 26, (opposite the surface which faces the recording medium, not shown) are operably connected to the printer for transmitting a printing signal. To access these conductors from the front surface of the flexible circuit 26, holes must be formed through the front surface of the flexible circuit 26 to expose the ends of the conductors. The exposed ends of the conductors are then plated with, for example, gold to form the contact pads 29 shown on the front surface of the flexible circuit 26.

Fig. 2 is an exploded view showing a back surface of the flexible circuit 26 removed from the printer pen 10. A second surface (or back surface) of the flexible circuit 26 includes a plurality of conductors 28 electrically conducted to and terminated by the contact pads 29 on the front surface of the flexible circuit 26.

As mentioned above, the back surface of the flexible circuit 26 on which the conductors 28 are formed includes a bonding system 30 formed from a latent curable composition, described above. The bonding system 30 encapsulates and insulates the conductors 28 to protect the encapsulated portion of the conductors on the flexible circuit 26 from ink exposure and potential shorting. The bonding system 30 is preferably formed from a latently curable composition attached to the back side of the flexible circuit 26 on which the conductors 28 are formed. More



preferably, the bonding system 30 is formed from a latently curable composition that is self-fastening.

Prior to forming the bonding system 30 on the flexible circuit 26, the latently curable composition may be provided as a film which is punched or die cut to a shape matching the area of the flexible circuit 26 to be bonded. If the latently curable composition includes a melt-flowable material, prior to lamination to the backside of the flexible circuit 26 (over the conductors), heat and pressure are used to temporarily soften the film to enhance adhesion to the flexible circuit 26 and assure that the conductors 28 are encapsulated adequately. If the latently curable composition includes a pressure sensitive material, only light heat and/or pressure may be necessary to enhance adhesion to the flexible circuit 26 and assure that the conductors 28 are encapsulated adequately.

Figs. 3a, 3b, and 3c illustrate more detail regarding the bonding system 30 laminated over the flexible circuit 26 and the conductors 28 in Fig. 2. Figs. 3a-3c are taken along line A-A in Fig. 2. The bonding system 30 is then aligned with respect to the flexible circuit 26 and tacked in place on the flexible circuit 26 by the application of pressure with or without heat.

After attaching the bonding system 30 to the conductors 28 on the flexible circuit 26, the resulting flexible circuit laminate is ready to be attached to a pen body. Attachment of the flexible circuit laminate to a pen body is done by the use of heated pressure pads. In this process, the self-fastening function of the latently curable composition is accomplished by causing the composition to soften and adhere to the plastic pen body. The latently curable composition is exposed to radiation and begins to bond to the pen body is shown in Fig. 3d.

Referring to Fig. 4, another embodiment of the present invention of a bonding system 30 is shown. In this embodiment, the bonding system includes a carrier layer 30c having a first surface and a second surface. Preferably, the carrier layer 30c is formed from a material that is chemically and thermally stable, more preferably the carrier layer 30c comprises a polyester. A self-fastening layer 30a is located on the second surface and a latently curable composition film 30b is located on the first surface. In manufacturing, the self-fastening layer is applied to

one surface of a desired substrate, such as the flexible circuit for example. Heat, pressure or both are applied to affix the construction to the flexible circuit 26. The construction attached to the flexible circuit is now exposed to radiation and the pen body 12 is affixed to the latently curable composition at some point during the open time of the latently curable composition. The self-fastening layer can be melt-flowable, as described above, pressure sensitive, or a combination of both. The self-fastening layer can be provided as a continuous layer or a pattern coated layer. One advantage in using this construction is that the carrier layer provides some strength of the construction during the manufacturing process. Suitable pressure sensitive materials are preferably selected from the group of a neoprene rubber, a nitrile rubber, a styrene-butadiene rubber, a natural rubber with a suitable amount of a hydrogenated rosin, a phenolic resin, a polyterpenic resin, polyethylene, an ethylene-vinyl acetate copolymer, a polyamide resin, acrylic polymer, and mixtures thereof. If the self-fastening material used is pressure sensitive, a substrate, such as a flexible circuit, can be adhered to the first surface of the carrier at any time prior to curing and stored.

A bonding system and a method for providing a bonding system which decreases the likelihood of electrical shorts due to ink contacting the conductors in a flexible circuit in an inkjet printer pen structure have been described. The precise shapes and dimensions of headland patterns will be determined by the type of printer chip design used.

Various modifications and alterations of this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention, and it should be understood that this invention is not to be unduly limited to the illustrative embodiments set forth herein.

## WHAT IS CLAIMED IS:

1. An inkjet printer pen structure comprising:  
a flexible circuit having a plurality of conductors formed on a first surface electrically connected to a plurality of contact pads located on a second surface of  
5 the flexible circuit;  
a body adapted to store and dispense ink; and  
a bonding system prepared from a latently curable composition located between the first surface of the flexible circuit and the body, wherein the bonding system operably attaches the conductors on the flexible circuit to the body.  
10
2. The inkjet printer pen structure of claim 1 wherein the latently curable composition comprises an epoxy-containing material, a polyester, a hydroxyl-containing material, and an effective amount of a photoinitiator.
- 15 3. The inkjet printer pen structure of claim 2 wherein the latently curable composition comprises a ratio by weight of hydroxyl-containing material to epoxy-containing material from about 0.1:1 to about 0.7:1.
4. The inkjet printer pen structure of claim 1 wherein the latently  
20 curable composition is self-fastening.
5. The inkjet printer pen structure of claim 1 wherein the bonding system comprises a film having a thickness of about 0.2 mm to about 0.025 mm.
- 25 6. The inkjet printer structure of claim 1 wherein the bonding system comprises:  
a carrier having a first major surface and a second major surface;  
a self-fastening layer on the first major surface of the carrier; and  
the latently curable composition on the second major surface of the  
30 carrier.

7. The inkjet printer pen structure of claim 1 wherein the bonding system further comprises a pressure sensitive material.

8. The inkjet printer pen structure of claim 4 wherein the latently curable composition is melt-flowable.

9. The inkjet printer pen structure of claim 2 wherein the photoinitiator is selected from the group of an aromatic iodium complex salt, an aromatic sulfonium salt, a metallocene salt, and mixtures thereof.

10. The inkjet printer pen structure of claim 2 wherein the photoinitiator is selected from the group of diaryliodonium hexafluorophosphate, diaryliodonium hexafluoroantimonate, a triaryl-substituted salt, a metallocene salt, and mixtures thereof.

11. The inkjet printer pen structure of claim 2 wherein the hydroxyl-containing material has a hydroxyl functionality of 2 or more.

12. The inkjet printer pen structure of claim 7 wherein the pressure sensitive material is selected from the group of a synthetic rubber, a natural rubber with an effective amount of hydrogenated rosin, a phenolic resin, a polyterpenic resin, polyethylene, an ethylene/vinyl acetate copolymer, a polyamide resin, an acrylic resin, and mixtures thereof.

13. The inkjet printer pen structure of claim 6 wherein the self-fastening layer comprises a pressure sensitive material.

14. The inkjet printer pen structure of claim 6 wherein the self-fastening layer is melt-flowable.

15. The inkjet printer pen structure of claim 6 wherein the carrier layer comprises a polyester.

16. A method for providing a bonding system in an inkjet printer pen,  
5 the method comprising the steps of:

applying a latent curable composition on a flexible circuit surface having conductors thereon;

exposing the latent curable composition to radiation for a time sufficient to initiate curing;

10 contacting the latent curable composition to a body adapted to store and dispense ink; and

forming a bonding system between the flexible circuit and the body, wherein the bonding system operably attaches the flexible circuit to the pen body.

15 17. The method of providing a bonding system in an inkjet printer pen of claim 16, wherein the latently curable composition comprises an epoxy-containing material, a polyester, a hydroxyl-containing material, and an effective amount of a photoinitiator.

20 18. The method of providing a bonding system in an inkjet printer pen of claim 16 wherein the bonding system is self-fastening.

19. The method of providing a bonding system in an inkjet printer pen of claim 18 wherein the latently curable composition is melt-flowable.

25

20. The method of providing a bonding system in an inkjet printer pen of claim 18 wherein the bonding system further comprises a pressure sensitive material.

21. The method of providing a bonding system in an inkjet printer pen of claim 19 wherein the latently curable composition further comprises an epoxy-acrylate, an epoxy-polyester, an epoxy-polycaprolactone, and mixtures thereof.

5 22. The method of providing a bonding system in an inkjet printer pen of claim 17 wherein the photoinitiator is selected from the group of an aromatic iodium salt, an aromatic sulfonium salt, a metallocene salt, and mixtures thereof.

23. The method of providing a bonding system in an inkjet printer pen  
10 of claim 17 wherein the photoinitiator is selected from the group of diaryliodonium hexafluorophosphate, diaryliodonium hexafluoroantimonate, triaryl-substituted salts, metallocene salts, and mixtures thereof.

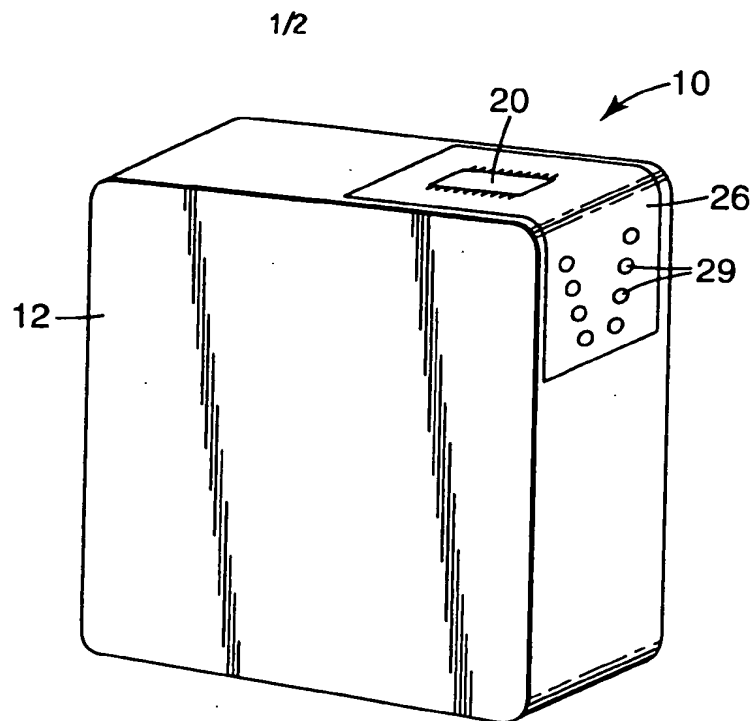
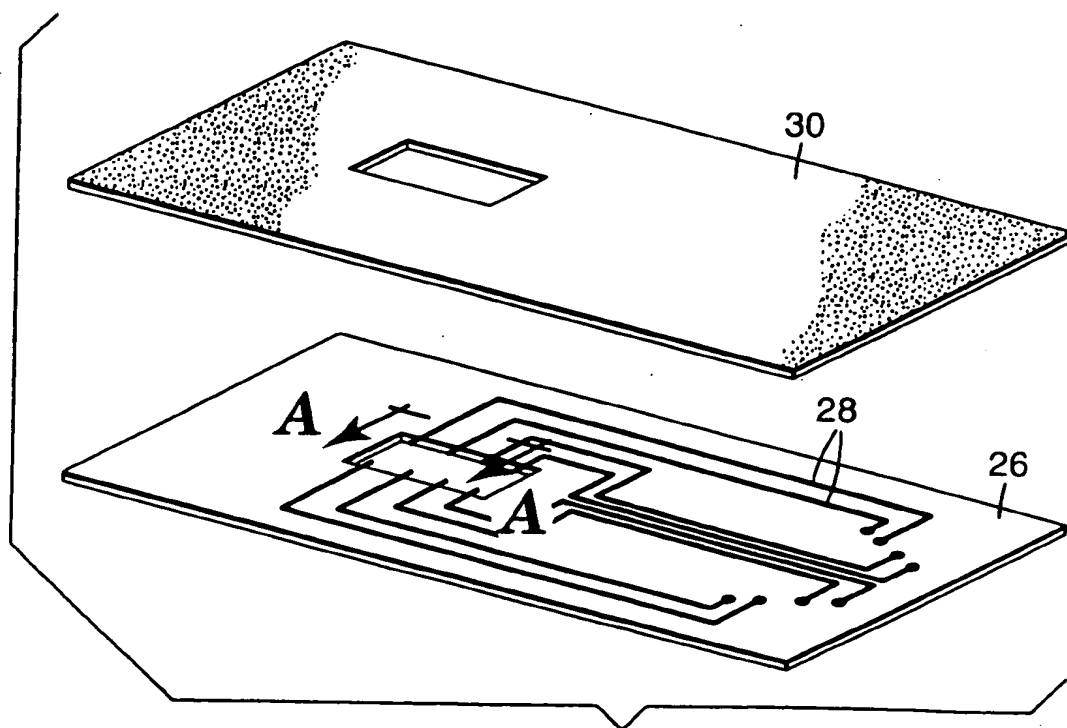
24. The method of providing a bonding system in an inkjet printer pen  
15 of claim 17 wherein the hydroxyl-containing material has a hydroxyl functionality of 2 or more.

25. The method of providing a bonding system in an inkjet printer pen of claim 20 wherein the pressure sensitive material is selected from the group of a  
20 synthetic rubber, a natural rubber with an effective amount of hydrogenated rosin, a phenolic resin, a polyterpenic resin, polyethylene, an ethylene/vinyl acetate copolymer, a polyamide resin, an acrylic resin, and mixtures thereof.

26. The method of providing a bonding system in an inkjet printer pen  
25 of claim 16 wherein the bonding system is a film having a thickness of about 0.2 mm to about 0.025 mm.

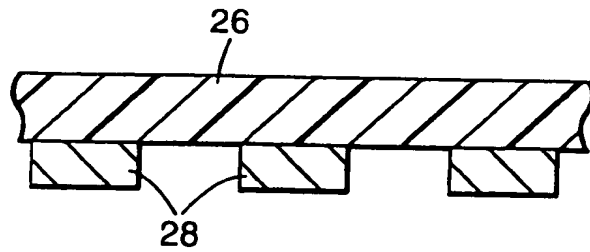
27. The method of providing a bonding system in an inkjet printer pen of claim 19 further comprising the step of applying heat and/or pressure to the  
30 latent curable composition.

28. An inkjet printer comprising the inkjet printer pen of claim 1.
29. A printer system comprising a computer operably connected to the inkjet printer of claim 28.

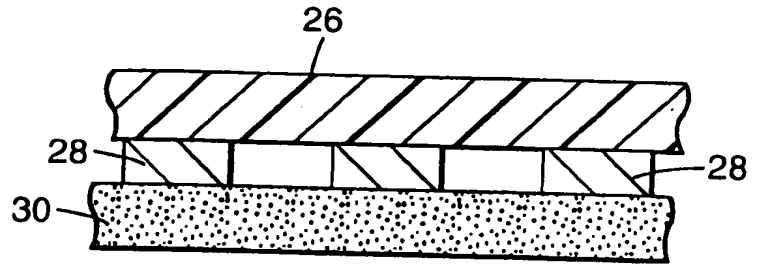
**Fig. 1****Fig. 2**



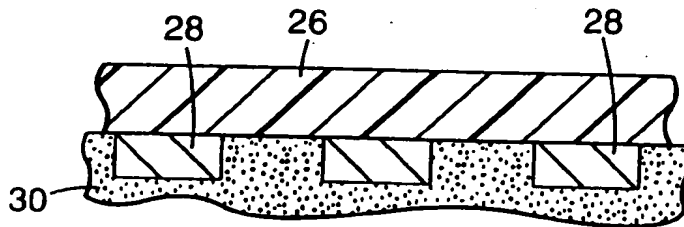
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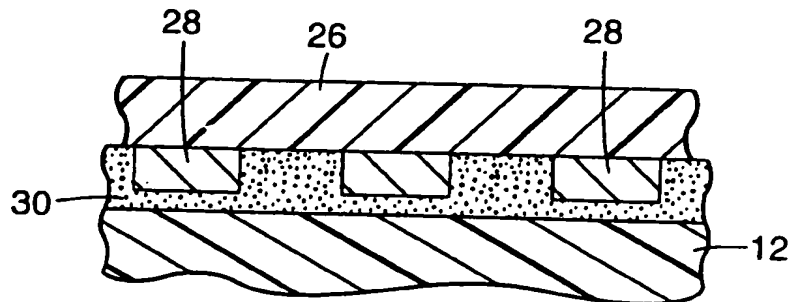
**Fig. 3a**



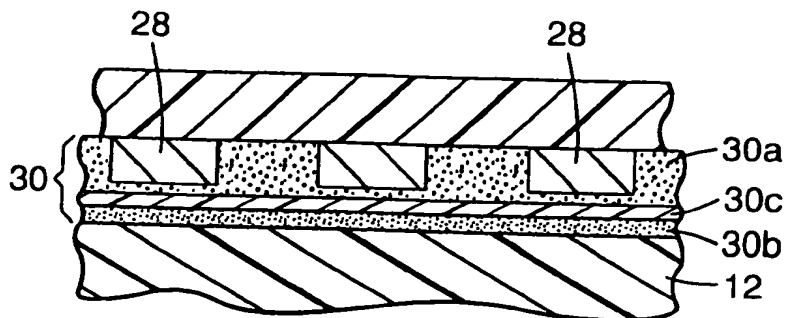
**Fig. 3b**



**Fig. 3c**



**Fig. 3d**



**Fig. 4**

# INTERNATIONAL SEARCH REPORT

I. National Application No

PCT/US 98/10717

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 B41J2/16

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Y	US 5 568 171 A (KEEFE ET AL) 22 October 1996 see column 6, line 44 - column 7, line 20 ---	1-4, 16-21
Y	EP 0 620 259 A (MINNESOTA MINING AND MANUFACTURING COMPANY) 19 October 1994 cited in the application see the whole document ---	1-4, 16-21
A	PATENT ABSTRACTS OF JAPAN vol. 096, no. 004, 30 April 1996 & JP 07 314671 A (CITIZEN WATCH CO LTD), 5 December 1995 see abstract ---	1
A	EP 0 581 298 A (CANON KABUSHIKI KAISHA) 2 February 1994 see the whole document ---	1,6
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

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- "&" document member of the same patent family

Date of the actual completion of the international search

31 August 1998

Date of mailing of the international search report

09/09/1998

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/10717

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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